# "Pseudo Cereal and their potential functional as Functional Food Ingredients"

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# Abstract

Traditional foods like buckwheat, quinoa, and amaranth have been rescued by the growing demand for healthier and more functional diets. Pseudocereals were extremely essential to ancient civilizations. Because they have a better nutritional value than many cereals in the current diet, they are gaining popularity in the markets. Furthermore, they may be beneficial to persons who are allergic to typical cereals. Pseudocereals have been successfully used in numerous baked items, fermented beverages, and extruded products. The main characteristics, nutritional value, and application of pseudocereals as functional food are the emphasis of this chapter.

# Introduction

Pseudocereals are dicotyledonous plant that resembles true cereals in function and composition. These contain no gluten and so offer a wide range of applications in gluten-free compositions. Pseudocereals are high in protein, fibre, and minerals, and they also have bioactive and health-promoting properties (Thakur and Kumar, 2019)**.** Cereals, pseudo-cereals, and legumes are good sources of proteins, lipids, carbs, vitamins, and minerals in the human diet. Probiotic strains are also used in cereals and pseudocereals for the fermentation process and the development of new functional food products (Sharma et al., 2021). Functional components such as antioxidants, dietary fibre, minerals, probiotics, and vitamins are abundant in fermented food products (Alvarez-Jubete et al., 2010). The development of novel functional foods is a popular trend in the food processing industry. Because of the presence of nutraceutical components, functional foods provide distinct health benefits beyond their nutritional features. Nutraceuticals are nutritional components with therapeutic qualities that aid in the maintenance of health, the modulation of immunity, and the avoidance of lifestyle disorders (Wang et al., 2012). Functional foods provoke the public's attention by preventing or delaying a variety of age-related issues such as osteoarthritis, alzheimer's disease, and diabetes (González-Sarrías et al., 2013). Because these grains contain several nutraceutical components, including them in one's diet has the potential to enrich one's diet while also providing health benefits, particularly for people with celiac disease who are gluten intolerant (Morales et al., 2021).

Cultivated plants that yield grains for human consumption include pseudocereals, cereals, legumes, oilseeds, and nuts, among others. Pseudocereals combine the terms cereal and pseudo, which refers to grains generated by grasses (Wrigley et al., 2015). Pseudocereals are grains that have nutritional properties similar to cereals but are generated by other botanical families (Martínez-Villaluenga et al., 2020). While cereals are produced by Poaceae species, pseudocereals occur in families of eudicots (Cactaceae, Amaranthaceae, Caryophyllaceae, Trapaceae and Polygonaceae) and monocots (Cyperaceae, Commelinaceae,and Zingiberaceae) (Schmidt et al., 2021). Quinoa (*Chenopodium quinoa* Willd, Amaranthaceae), buckwheat (*Fagopyrum esculentum* Moench and *Fagopyrum tataricum* Gaertn. Polygonaceae) and amaranth (*Amaranthus* spp., Amaranthaceae) are currently the main pseudocereals crops in the world (Wrigley et al., 2015; Martínez-Villaluenga et al., 2020). They are nutritionally high in protein content and quality, as well as the absence of gluten. For the management of these plants, the vast genetic variety and resilience to severe climatic conditions are particularly important traits (Joshi et al., 2018). Pseudocereals are "subexploited foods" and includes non-grasses plant species that are not related to cereals but have similar qualities and functions. "Subexploited foods" are foods that were part of various population diets for years before being displaced in the early twentieth century by foods that now dominate the world population diet (Morales et al., 2021). Pseudocereal crops have been proposed as significant resources for food security since the world's population is expected to exceed 9,700 million people by 2050. The Food and Agriculture Organization (FAO) defines food security as a condition in which all people have physical and economic access to sufficient, safe, and nutritious food that fits their dietary needs and preferences for an active and healthy life at all times (FAOSTAT, 2015). Pseudocereals are economically, socially, ecologically, nutritionally, and functionally important due to their agronomic qualities, ecological adaptation to unfavourable environments, and high nutritional content (Morales et al., 2021). Latin American countries such as Bolivia, Ecuador, and Peru were the biggest producers of these pseudocereals because they ate them as a staple cuisine. Following the conquest by the Spanish, the cultivation of these foods declined, giving way to grains such as wheat and barley. Furthermore, because some pseudocereals include anti-nutritional elements that require specific washing techniques to reduce their levels and make the food suitable for human consumption, pseudocereal manufacturing was often intended for animal feed (Arendt and Dal Bello, 2011). Other countries, such as China and Russia, are now major producers of pseudocereals like buckwheat (close to 1 million tonnes in 2018) (FAOSTAT, 2018). Despite their importance in the diets of many historical civilizations, pseudocereals account only a modest percentage of global grain production today. However, in a time when much is being said about food security, nutritional quality, and food usefulness, the cultivation of these plants has the potential to grow in the near future (Schmidt et al., 2021).

# Pseudocereals as Functional Foods

Food is any substance that can nourish an organism when digested (Schmidt et al., 2021). Functional meals, on the other hand, have the ability to influence the body's physiological functioning in addition to satisfying their basic nutritional duties (Silva et al., 2016). As a result, the health and quality of life of those who consume them improves, while the risk of disease decreases (Iglesias et al., 2010). The notion of functional food first emerged in Japan in the 1980s, when the Japanese Ministry of Health, Labour, and Welfare decided that some foods would be given a seal of approval for use in the health field (FOSHU: Foods for Specified Health Use) (Costa et al., 2016). Functional foods were classified in the early 1990s in the United States of America (USA) as foods that had a favourable influence on an individual's health after ingestion (Caballero et al., 2015). After many discussions, the European Union decided in 1999 to streamline the necessary procedures for demonstrating that particular minerals present in certain foods have a favourable impact on health (Schimdt et al., 2021). Although there is no legal definition of "functional foods" in Brazil, the legislation confirms the functional and health aspects of foods by setting rules for the registration of foods that contain these properties in their compositions. The molecules that each functional meal produces determine the method of action in the body (Costa et al., 2016). Pseudocereals are considered functional foods because of their great nutritional value. The various bioactive components of various pseudocereals are represented in Figure 1.Buckwheat, for example, includes carotenoids (beta-carotene and lutein), which regulate cell antioxidant activity (Tuan et al., 2013) and dietary fibres, both water soluble and insoluble, which lower blood cholesterol and glucose levels. Buckwheat is also the only grain that includes rutin, a flavonoid that helps to strengthen blood vessels (Joshi et al., 2019). Amaranth has the ability to lower serum cholesterol levels in general, primarily to the combined action of various components (Schimdt et al., 2021). Amaranth oil contains more phytosterols than other vegetable oils, which have hypocholesterolemic properties. β-sitosterol (607 μg 100 g−1), makes up 95% of total sterols, followed by campesterol (8.8 μg 100 g−1) and stigmasterol (5.6 μg 100 g−1). Other products, such as soybean oil, olive oil, cotton oil, peanut oil and, contain; 153; 303; 131 and 123 μg 100g-1 of β-sitosterol, respectively (Marcone et al., 2003). The amaranth grains' soluble fibres and the unsaturated hydrocarbon squalene have hypocholesterolemic properties. Squalene also has anticarcinogenic and antioxidant properties (He et al., 2002). Quinoa and amaranth, in addition to these substances, have higher protein levels than grains, making them ideal functional foods (Schimdt et al., 2021).

# Nutritional Characteristics of Pseudocereals

## Buckwheat

Buckwheat is a member of the Polygonaceae family and genus (Fagopyrum spp). It is the best growing crop in such regions since it grows at higher elevations for a short period of time (3-4 months). Buckwheat can withstand harsh temperatures, a lack of water, low soil quality, and a variety of environmental conditions (Nalinkumar and Singh, 2020). Proteins, polysaccharides, dietary fibre, lipids, polyphenols, and micronutrients are all present in buckwheat grain (Qin et al., 2010). Whole buckwheat groats are the hulled seeds and contain 550 mg/g starch, 120 mg/g protein, 70 mg/g total dietary fibre (TDF), 40 mg/g lipid, 20 mg/g soluble carbohydrates, and 180 mg/g other components such as organic acids, phenolic compounds, tannins, phosphorylated sugars, nucleotides, and nucleic acids (Im et al., 2003). Buckwheat flour provides roughly 7.7% more fat and 15-30% more fibre than wheat flour (Lin et al., 2009; Qin et al., 2010). In addition to these advantages, buckwheat has a lower real protein digestibility of 79.9% when compared to maize (93.2%) (Belton and Taylor, 2002). The decrease in the protein digestibility of buckwheat's can be linked to its antinutritional properties, such as α-amylase inhibitors, trypsin inhibitors, polyphenols and phytic acid (Wang and Zhu, 2015). Buckwheat is one of the leading causes of anaphylaxis/food allergy in South Korea and Japan (Loh and Tang, 2018). Low molecular weight proteins found in buckwheat flour may be the source of many allergies (Taylor and Awika, 2017).

## Amaranth

Grain amaranth flour contains 66.17 g (carbohydrates), 9.3 g (dietary fibre), lipids (ω−3 and ω−6), 3.04 g (minerals), squalene, tocopherols, phenolic compounds, flavonoids, phytates, and vitamins making it a "super food". Grain amaranth flour has a protein level of 20.62 % higher than wheat flour (Brennan et al., 2012). It helps in the reduction of inflammation and cholesterol, prevention of diabetes and constipation, and keeping bones strong (Soriano-Garcia et al., 2018).

## Quinoa

Quinoa (*Chenopodium quinoa* Willd.) belongs to the Chenopodiaceae family. Chenopodium is a genus of over 250 species that can be found all over the world. It is a graniferous plant native to South America and has been domesticated for thousands of years by people living in the Andes, primarily in Peru and Bolivia (Filho et al., 2017). One serving of quinoa (approximately 40 g) meets a major portion of the dietary recommendations (RDA) primarily vitamins, minerals, and essential amino acids (Vilcacundo & Hernández-Ledesma, 2017). Quinoa seeds contain a protein concentration of 14.1% on average, ranging from 8-22%. On a dry basis, cereals like barley, wheat, and rice (Oryza sativa L.) have an average protein level of 13.8; 10.7; and 7.0%, respectively, whereas most legumes have a greater protein content, with 22.1 and 33.6% in beans and peas (*Phaseolus vulgaris* L.). The protein is primarily present in the endosperm. Albumin and globulins make up 44 to 77% of the protein fraction, while prolamins, a group of gluten-related proteins, make up only 0.5 to 7.0% of the protein fraction or are even absent in some kinds (Fuentes et al., 2013; Schimdt et al., 2021).

# Utilisation of Pseudocereals for Food Products

## Gluten-Free Foods

The consumption and demand for gluten-free products has increased all over the world due to an increased prevalence of gluten-related disorders like CD, or the intolerance to gluten and wheat, called “non-celiac wheat or gluten sensitiv­ity” (NCWS or NCGS) (Shewry and Hey, 2016). A study by Junker et al. (2012) identified amylase–trypsin inhibitors (ATIs) as potential triggers of innate im­munity in wheat, which should be responsible for NCWS or NCGS. In addition to persons suffering from the aforementioned disorders, glu­ten-free products are increasingly being purchased by people because of their health-promoting image, especially if they contain pseudocereals. During the last ten years many gluten-free products have been developed and marketed, leading to a great increase in consumption (Shewry and Hey, 2016). As result of the efforts of the research community, products with higher functional and nutritional quality have been developed. Generally pseudocereals are very low in prolamins because they are dicotyledonous plants and hence do not contain protein fractions that are toxic to CD patients. Although it is only recently that some specific studies have been undertaken to actually prove this. In summary, the consumption of amaranth and other pseudocereals is safe for celiacs and thus their products can be included in a gluten-free diet (D’Amico et al., 2017).

The use of amaranth, quinoa and buckwheat for the production of gluten-free pasta was studied by Schoenlechner et al. (2010). The results showed that pasta produced from amaranth had decreased texture firmness and cooking time, while pasta from quinoa mainly showed increased cooking loss. In buckwheat pasta, the least negative effects were observed. By combination of all three raw materials into one flour blend in the ratio of 60% buckwheat, 20% amaranth and 20% quinoa, the dough matrix was improved. Dough moisture had to be low­ered (30% vs. 34.5% in wheat pasta). The addition of isolated protein (the most suitable was egg albumen) had the highest effect on improving pasta firmness. For the production of gluten-free pasta, the role of starch and its properties are important (Marti et al., 2011). Phenomena related to starch retrogradation were found to play a central role for the final texture of the products (Mariotti et al., 2011). Thus more attention is being paid on the technology of pasta mak­ing, utilising pre-gelatinised flours or dough, or applying different temperature regimes (Marti and Pagani, 2013). Both approaches seem to be promising for improving gluten-free pasta quality. De Arcangelis et al. (2020) used gelatinized buckwheat flour alone or in combination with maize and rice and showed that gelatinization of the three flour blends allowed to obtain pasta with the highest quality and texture. On the other hand, Singh and Liu (2021) evaluated roasting and jet-cooking of amaranth flour to improve noodle making. Raw, jetcooked and roasted amaranth flour noodles were overall softer than those produced with wheat flour. Jet-cooking was less suitable for noodle making due to its partial disintegration of the pasta during cooking, whereas roasted amaranth flour showed a good potential for replacing wheat flour in gluten-free noodles. Further hydrothermal treatments have shown to improve the technological and physiological properties of amaranth pasta (Rudra et al., 2020), while the application of sourdough additionally improved the nutritional quality of quinoa pasta (Carrizo et al., 2020).

## Beverages /Drinks

Cereal beverages are indigenous to many regions in the world, but also in the Northern Countries they are more commonly consumed as an alternative to milk or to complement a healthy or environmentally friendly life style. The demand for non-dairy beverages based on plants is therefore a growing market (Bender and Schönlechner, 2021). Dezelak et al. (2014) analysed the brewing attributes of quinoa in comparison with barley, reporting that it had lower malt extracts, longer saccharification times, and higher total protein and fermentable amino nitrogen contents. The quinoa beer contained some distinctive volatile substances not found in barley beer and had many unique properties. Pineli et al. (2015) reported that quinoa milk provides a novel alternative to current milk-substitute products that cause no known adverse effects in humans and that have increased protein content and a low glycaemic index. Lee and Park (2013) varied the concentrations of buckwheat saccharification solution added to milk, followed by fermentation with commercially available mixed strains of lactic acid bacteria. They observed that undesirable compounds, such as acetic acid and 2-butanone, decreased as the buckwheat solution concentration increased, so the flavour quality of plain yogurt improved by adding buckwheat (Lee and Park, 2013). Tartary buckwheat sprout was also mixed with mung beans, black rice, and skimmed milk with sweeteners to develop a yogurt with health-promoting properties (Wang et al., 2013). Buckwheat tea is a popular health product in Asian and European countries, made from flowers, leaves or hulls (Giménez-Bastida et al., 2015). In China it is common to find buckwheat tea. It is produced by soaking, steaming, dehulling, and baking buckwheat seeds. The final buckwheat tea product is in granule form, with an attractive yellowish colour and pleasant baked flavour (Qin et al., 2014).

## Infant food

Quinoa is the pseudocereal most used for infant food. An infant food product was manufactured by drum-drying quinoa flour slurry by Ruales et al. (2002). It was shown that the product was a potential source of valuable nutrients such as protein, vitamin E, thiamine, iron, zinc and magnesium for preschool children. Mezquita et al. (2012) also developed a beverage with a high protein content for the diet of pre-schoolers by using a mix of Chilean mesquite, lupin and quinoa. Repo-Carrasco et al. (2003) reported that quinoa and kañiwa can be used in weaning food mixtures. They formulated two dietary mixtures, quinoa–kañiwa–beans and quinoa–kiwicha–beans, both with high nutritional value. The mixtures had protein efficiency ratio (PER) values close to that of casein (2.5): 2.36 and 2.59, respectively. Cook et al. (1997) evaluated the absorption of iron contained in, or added to, dry cereals used for infant feeding (wheat, corn, rice, millet, oat, and quinoa). They concluded that the type of cereal grain has little influence on iron bioavailability of infant cereals with the exception of high absorption in corn and modestly low absorption in quinoa, probably because of its high levels of phytates (Haros and Sanz-Penella, 2017).

## Extrusion cooking

Extrusion cooking is a process where at high temperatures and high pressure, induced by high shear forces, starchy materials is cooked and transformed into ready-to-eat products in a very short time. Starch is gelatinized, the proteins are denatured, while nutrients are retained to a high extend, due to the rather short exposure to heat. The obtained extrudates can be formulated and consumed directly as snacks or breakfast cereals, overall, a wide range of consumer endproducts can be manufactured by this technology (Bender and Schonlechner, 2021). In this regard, Guerra-Matías and Areas (2005) investigated starch digestibility in an extruded product formulated with amaranth. The glycaemic index and insulinemic response were determined in healthy women. The results indicated high glycaemic response with fast digestibility in the amaranth snack and white bread (as control), whereas the snack showed a greater capacity for stimulating insulin release than the control. Ramos Diaz et al. (2017) investigated the extrusion cooking properties of maize blended with amaranth or quinoa, and achieved expanded extrudates even at an addition level of up to 50%. Content of fatty acids and tocopherols were reduced in the extrudates, while the content of total phenolic compounds and folate were only little affected. This study proved that extrudates containing up to 50% amaranth or quinoa can maintain some key physical properties (e.g., high SEI, low stiffness) and the added nutritional value (e.g., increased content of folate). Replacement of wheat or maize by amaranth or buckwheat flours for the production of changed the nutritional quality of extruded breakfast cereals also in the study of Brennan et al. (2012). All of the extruded products made with the inclusion of pseudocereals showed a significant reduction in readily digestible carbohydrates and slowly digestible carbohydrates compared to the control product during predictive in vitro glycemic profiling. For quinoa it was shown that extrusion cooking increased protein crosslinking in quinoa and the amount of soluble fibre (Kuktaite et al., 2021).

# Foods and non-foods uses

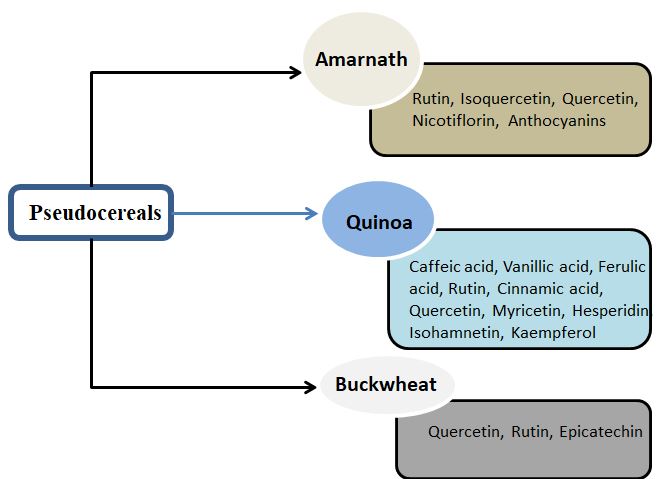
The use of pseudocereals in food has increased substantially, and research has even extended to non-food applications. Quinoa has been proposed as a crop for NASA's CELSS (Controlled Ecological Life Support System). Plants will be used to remove carbon dioxide from the atmosphere, providing food, oxygen, and water for crews on long-term human space trips, according to the CELSS idea. Quinoa was chosen because of its nutritional benefits and great productivity. To get the correct amino acid balance, CELSS has had to mix the nutritional qualities of multiple crops in the past, but quinoa appears to provide it on its own (Schlick and Bubenheim, 1996). Quinoa is a nutritious, healthful, and easily farmed food that NASA feeds to astronauts on long space journeys (TWB, 2014). Aside from that, buckwheat has been used to make a variety of foods such as tea, yoghurt, vinegar, alcoholic beverages and dark sauce (Bender and Schönlechner, 2021). Quinoa milling fractions with high fibre content have been employed as binders in the manufacturing of bologna-style sausages. The fibre-rich quinoa fraction improved the emulsion's stability and reduced the sausage's lipid oxidation and water activity. It was determined that adding nitrite to the product was unnecessary because the quinoa fractions already provided enough colour (Fernandez-Lopez et al., 2020). Quinoa and buckwheat flour have also been employed as binders for beef patties, with positive results in terms of nutritional, sensory, and shelf-life qualities (Bahmanyar et al., 2021). Amaranth and quinoa starch could be utilised as a thickening for frozen foods because of their great freeze-thaw durability and low amylose concentration. Salad dressings, cream soups, sauces, and pie fillings could all benefit from their resistance to retrogradation. Buckwheat has been the most researched pseudocereal in the non-food world. The production of biopolymers for the development of edible and biodegradable films is another unusual application of pseudocereals. This could be a means to expand their applications and open up new markets, as well as a way to replace non-biodegradable synthetic plastic in pharmaceutical and food applications (Tapia-Blácido et al., 2007). Buckwheat protein from distillers dried grains has been used to make composite edible films for food packaging (Wang et al., 2017), and buckwheat peptides could be employed as a functional ingredient in nutraceutical research (Li et al., 2019). Quinoa flour has also demonstrated the potential to create appropriate biofilms for use in food packaging. When compared to polyethylene films, they have a higher blocking ability and have less solubility and water permeability than certain polysaccharide films (Salas-Valero et al., 2015).

# Conclusion and Future Perspective

Despite the fact that they are neither grasses nor actual cereal grains, plants that produce fruits or seeds that are utilised and consumed as grains are referred to as pseudocereals. Many bioactive substances with health-promoting properties, such as polyphenols, phytosterols, squalene, and saponins, are abundant in preudocereals. Soaking, germination, popping, heating, and fermentation have all been shown to improve the nutritional value of these grains as well as the products created by their incorporation. These can be widely used in the manufacture of gluten-free processed items such as pasta, bread, and confectionery products due to their gluten-free properties. The necessity for gluten-free products based on pseudocereals to be commercialised is significant, as the market for these items is severely lacking. Pseudocereals could also be used to create new probiotic meals. Pseudocereals should be included in the everyday diet of the global population due to their great nutritional value. Interest in these meals is growing as the nutritional and bioactive qualities of these plants become well understood. Pseudocereals have a lot of potential as a natural source of biologically active compounds, especially peptides and protein hydrolysates, which have anti-inflammatory, antioxidant, and antihypertensive properties, and pseudocereal-based products could be very useful in improving celiac population health and quality of life. Yet, substantial research is needed, particularly in vivo studies in animal models and clinical trials, to show that pseudocereal protein derived peptides have health advantages and to study the mechanisms of action that contribute to bioactive qualities.

**Table 4: Pseudo-cereals based gluten free diet**

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| --- | --- | --- | --- | --- |
| **Gluten free foods** | **Type of pseudocereals** | **Ingredients** | **Remarks** | **References** |
| Noodles | Quinoa | Potato starch, extruded and non-extruded quinoa, tara gum with or without addition of lupine flour, vegetable proteins and Pox enzyme | High noodle quality, protein and fiber contents | Linares-García et al. (2019) |
| Fermented  Beverage | Quinoa | Quinoa seeds fermented with lactic acid bacteria strains | High protein, fiber, vitamins and minerals levels; viable and stable microbial counts  during storage microbial load during  storage time | Ludena-Urquizo et al. (2017) |
| Pasta | Quinoa and amaranth | Rice flour replaced by quinoa and amaranth flours and egg white | Good elasticity and sensory acceptability | Makdoud and Rosentrater, (2017) |
| Spaghetti | Amaranth | Dried and extruded potato pulp,  amaranth flour at different  concentrations | Higher yield, better color and cooking characteristics than fresh commercial wheat pasta | Bastos et al. (2016) |
| Snacks | Quinoa | Quinoa flour with spices | Good water activity, textural and sensory acceptability. | Khalon et al. (2016) |
| Wafer sheet | Buckwheat | Rice replaced by corn, chestnut or buckwheat flours | Rice-buckwheat flours based wafer sheet formulations had the closest value of consistency, flow behavior index, hardness and fracturability to wheat-based wafer sheet | Mert et al. (2015) |
| Bakery  products | Quinoa | Rice and oat flour replaced by roasted quinoa flour | Good sensory attributes | Kaur and Kaur, (2017) |
| Cookies | Buckwheat | Rice flour replaced by  tartary buckwheat malt  or flour | Higher total phenolic, rutin and quercetin contents and antioxidant activity and lower glycemic index | Molinari et al. (2018) |
| Cookies | Quinoa | 100% quinoa flour | Exhibited good textural and sensory quality and high antioxidant activity | Jan et al. (2018) |
| Beef burger | Quinoa and buckwheat | Soy protein powder and bread crumb replaced by quinoa and buckwheat flour | Higher content of mineral, sensory acceptance and shelf life stability | Bahmanyar et al., 2021 |
| Bread | Buckwheat | Chia seed and buckwheat flour | Higher amount of protein, insoluble dietary fibers, ash, and alpha-linolenic acid; Improvement in total antioxidant capacity | Costantini et al., 2014 |
| Bread | Buckwheat | 100% buckwheat flour | Enhancement of iron, zinc, calcium potassium, phosphorus, magnesium and copper; Decrease in bread specific volume  Increase in bread hardness | Sayed et al. (2016) |
| Bread | Quinoa and amaranth | Rice flour, potato starch, cassava starch and sour tapioca starch replaced by quinoa or amaranth  whole flours | Showed similar specific volume, firmness and water activity; High protein, lipid and ash content and larger alveolar area | Alencar et al. (2015) |
| Flatbread | Quinoa | Mixture of quinoa, peanut  oilcake and broccoli/beet | Higher protein and mineral contents and acceptance | Khalon et al. (2019) |

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**Fig 1: Bioactive compounds of pseudocereals**

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